



PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION.

Improvements relating to Apparatus for Plotting the Directional Characteristics of Wave Propagating and/or Receiving Devices, such as Radio Aerials.

We, CHARLES WALTER MILLER, of 58, Manor Avenue, Sale, in the County of Chester, MICHAEL CROWLEY CROWLEY-MILLING, of "Belmont," Colwyn Bay, in the County of Denbigh, both subjects of the King of Great Britain, and METROPOLITAN-VICKERS ELECTRICAL COMPANY LIMITED, of St. Paul's Corner, 1-3, St. Paul's Churchyard, London, E.C.4, a British Company, do hereby declare the nature of this invention to be as follows :

This invention relates to apparatus for obtaining the polar characteristics of radiating devices such as aerial systems. The invention has an important application *inter alia* in aerial systems for microwaves. It has, however, other applications.

The present invention comprises apparatus for determining the polar characteristics of aerial systems in which signal generating apparatus feeds a transmitting aerial, the output of which is received by a receiving aerial, in which means are provided for varying the bearing and/or elevation of the aerial under test, together with indicating and/or recording apparatus actuated on the one hand in accordance with the direction of said test aerial, and on the other hand in accordance with the amount of variation in amplitude of the transmitted signals necessary to maintain the received signals at a predetermined strength.

Preferably in carrying out the invention the aerial to be tested is the transmitting aerial and this is rotated about an axis, whilst the receiving aerial is maintained stationary. Normally in such a case the transmitting aerial will be rotated about a vertical axis to determine its distribution in the horizontal plane, whilst in cases in which it is desired to obtain the distribution of energy in a vertical plane provision may be made whereby it can be rotated about a horizontal axis.

be a receiving aerial, in which case the latter

Alternatively of course the test aerial may 45 would be rotated and the transmitting aerial maintained stationary.

In order that the invention may be more clearly understood reference will now be made to the accompanying drawing which shows in block form one example of apparatus embodying the invention.

In the arrangement shown the transmitting aerial is the aerial under test and the test aerial together with transmitting apparatus and recording apparatus is mounted in a cabin which is rotatable about a vertical axis.

The transmitter portion of the equipment comprises an oscillator which is square-wave modulated at a convenient frequency, for example a 3 cm. oscillator modulated with a 100 kc. square wave. The energy is fed to a normal manually operated attenuator for setting the general level which attenuator is indicated in the diagram as a setting attenuator, whence the energy passes to the test aerial through a calibrating attenuator operated by servo mechanism.

The receiver equipment is placed at some suitable distance from the transmitter and the energy received by the receiver aerial is fed to a rectifier from which is obtained the 100 kc. square wave of the modulation. This square wave undergoes amplification in a tuned amplifier and because of the narrow bandwidth the resultant amplified signal is a sine wave of the fundamental frequency of the square wave modulation. This sine wave voltage is fed by means of cable back from the receiving station to the transmitter and recording station where, after further amplification and if necessary passage through selective filters to reduce noise level, it passes through a rectifier and thus produces a D.C. voltage. The D.C. voltage is fed into a balancer unit where it is balanced against a stabilised D.C. reference voltage. The output from the balancer is fed to a servo

- motor and it will be appreciated that the output from the balancer will depend upon the value of the D.C. voltage from the receiver relative to the reference voltage and 5 will operate the servo in one direction or the other according to whether the received signal is greater or less than the reference voltage. The servo motor is operatively connected with the calibrating attenuator in the transmission chain and varies the setting of this so as to increase or reduce the energy fed to the transmitter test aerial in such manner as to maintain the received signals constant.
- 10 It will thus be appreciated that the apparatus sets itself in such a way that the received signal is at a constant level irrespective of the characteristics of the rectifiers and amplifiers employed provided that these remain constant during a plot. At the same time the servo unit operates a recorder unit simultaneously with its operation of the calibrating attenuator so that a record and, or indication is obtained of the setting of the 15 calibrating attenuator necessary to maintain the received signals at a constant level and this will, of course, be a measure of the energy propagated from the test aerial in the direction of the receiver. It is assumed that the transmitter aerial is rotated and the recorder is at the same time moved in accordance with the direction of the transmitter aerial, for example the recorder may comprise a drum on the periphery of which is a recording pen which is moved axially by the servo motor, whilst at the same time the drum is rotated in accordance with the 20 direction of the transmitter aerial.
- 25 In the arrangement embodying the invention the servo unit may comprise a D.C. motor whose armature is supplied with constant current and having a split field winding. The balancer unit may for example comprise a pair of valves having a common cathode coupling and the current through one of which valves is controlled by the rectified output from the receiver, whilst current through the alternate valve is maintained constant. These valves will respectively control the currents through windings of the servo motor field system which windings would act in opposition, the valves 30 preferably operating through additional amplifying valves. The servo motor may conveniently operate a cam or the like operating the attenuator. The use of a cam enables the attenuation scale to be given any desired characteristic, either linear or logarithmic. Furthermore, by choice of suitable gearing, any desired angular scale may be achieved.
- 35 Conveniently means are provided for changing the ratio of the gearing so as to change the angular scale.
- 40 In some cases it may be convenient to provide the servo motor with velocity feed-

back to maintain stability; this might be obtained by a small tachometer generator giving a voltage feedback proportional to velocity.

45 According to one construction the recorder comprises a drum which carries graph paper around its periphery and is rotated through gearing controlled from the movement of the cabin housing the transmitter and recorder apparatus. Thus the angular positioning of the drum about its axis is proportional to the direction of the test aerial.

50 With such an arrangement the recording may be performed by a pen which traverses the periphery of the drum axially and is positioned by the servo motor, for instance by means of a lead screw. With such an arrangement as the transmitter aerial is rotated a graph on cartesian co-ordinates may be obtained showing the variation in field strength at constant distance from the test aerial as a function of bearing. This curve is normally known as the polar diagram of the test aerial.

55 Alternatively it will be appreciated that the transmitter and recorder cabin may be stationary and only the test aerial rotated, the recorder in such a case being controlled mechanically or otherwise in accordance with the position of the test aerial.

60 It is contemplated that in employing such apparatus the test aerial will be moved relatively rapidly through the range of positions over which the graph is to be obtained by the recording apparatus. The recording apparatus may alternatively be photographic, obtained for instance by deflecting an electron beam falling on a fluorescent screen having a backing of photographic material, whilst in some cases a visual indication may be obtained by such apparatus where the luminescent screen has a long afterglow.

65 In a model for testing 3 cm. aerials, the oscillator is a small reflex klystron pulsed with equal mark, space ratio at 100 kc.s. repetition and the attenuator takes the form of a piece of carbon-coated bakelite which is pushed into the waveguide system by means of a cam operated by the servo motor. In this case the receiving aerial is an 18" dia. parabolic dish and the signal rectifier is a silicon crystal.

70 One of the limits to sensitivity is noise level and in order to minimise this it is desirable that the overall bandwidth of the amplifier system should be as small as possible. In order to obtain a narrow bandwidth quartz crystal filters may be introduced at suitable points in the circuit.

75 An alternative way of obtaining narrow bandwidth is to replace the rectifier immediately prior to the balancer unit by a mixer arrangement. In this the normal type of multigrid mixer valve may be used, the

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signal grid being connected to the incoming modulation signal (sine wave) from the receiver whilst the injection grid is connected, through suitable phasing networks, to the sine wave generator controlling the pulsing of the oscillator. Thus in the mixer two signals of identical frequency (f) are mixed, producing a D.C. voltage, and a voltage of frequency $2f$. (These take the place of voltages of frequencies $f_1 - f_2$ and $f_1 + f_2$ of the normal type of mixer.) Any noise from amplifiers, etc., will produce voltages of frequencies from zero up to some frequency F determined by the bandwidth of the amplifier. By passing the output from the mixer through a low pass filter the noise can be largely eliminated and the D.C. passed to the balancer unit. It will be appreciated that in the original scheme when a normal rectifier is used, both noise and signal produce a D.C. voltage and no further filtering is possible.

Further it will be appreciated that a balanced type of mixer may be employed if desired.

Instead of using a D.C. reference voltage in the balancer unit a small fraction of the oscillator power may be rectified to produce a voltage proportional to the oscillator power and this voltage may be used as the reference voltage. This eliminates error due to variation of oscillator power during the plotting of a curve.

According to a further feature means are provided for varying the speed of rotation of the test aerial in accordance with the rate of change of the attenuator position, this enables curves to be plotted at maximum average speed since the aerial may be rotated relatively slowly over those portions where the rate of change of the attenuator position is great and relatively rapidly over those portions where the rate of change of the attenuator position is small.

The maximum speed of aerial rotation is of course under any conditions limited to such a speed that the servo mechanism operating the attenuator may accurately follow the variations. A particular manner of achieving this is to control the speed of rotation of the hut by a servo mechanism which in turn is controlled by the magnitude of the voltage generated by the tachometer generator associated with the attenuator servo mechanism. This voltage is of course proportional to the rate of change of the attenuator setting.

Whilst the invention has been described in respect of its application to aerials it will be appreciated that it is applicable to other types of radiating apparatus such as light, heat or sound emitters for example.

Dated the 18th day of September, 1947.

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Agent for the Applicants.

COMPLETE SPECIFICATION.

Improvements relating to Apparatus for Plotting the Directional Characteristics of Wave Propagating and/or Receiving Devices, such as Radio Aerials.

We, CHARLES WALTER MILLER, of 58, Manor Avenue, Sale, in the County of Chester, MICHAEL CROWLEY CROWLEY-MILLING, of "Belmont," Colwyn Bay, in the County of Denbigh, both subjects of the King of Great Britain; and METROPOLITAN-VICKERS ELECTRICAL COMPANY LIMITED, of St. Paul's Corner, 1-3, St. Paul's Churchyard, London, E.C.4, a British Company, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to apparatus for obtaining the directional characteristics of wave propagating or receiving devices such as aerial systems. The invention has an important application in radio aerial systems for microwaves.

It is known to plot polar characteristics of aerial systems by rotating the receiving aerial and periodically plotting the strength of the received signals automatically on a drum recorder.

Such an arrangement, however, needs calibration and if a high degree of accuracy is required such calibration must be carried out fairly frequently to allow for changes in characteristics of the receiving equipment due for instance to ageing of the valves.

The present invention comprises apparatus for determining the directional characteristics of a wave propagating and/or receiving aerial comprising means for causing said apparatus under test to transmit to or receive from co-operating apparatus, moving said apparatus under test angularly with respect to said co-operating apparatus, control apparatus acting on the propagating or receiving apparatus in such manner as to maintain the receiver output at a substantially constant amplitude and means for utilising the setting of the control apparatus to provide a measure of the relative efficiency

of the received signals automatically on a drum recorder.

Such an arrangement, however, needs calibration and if a high degree of accuracy is required such calibration must be carried out fairly frequently to allow for changes in characteristics of the receiving equipment due for instance to ageing of the valves.

The present invention comprises apparatus for determining the directional characteristics of a wave propagating and/or receiving aerial comprising means for causing said apparatus under test to transmit to or receive from co-operating apparatus, moving said apparatus under test angularly with respect to said co-operating apparatus, control apparatus acting on the propagating or receiving apparatus in such manner as to maintain the receiver output at a substantially constant amplitude and means for utilising the setting of the control apparatus to provide a measure of the relative efficiency

of the apparatus under test at different angular positions.

The invention also comprises apparatus for determining the directional characteristics of radio aerial systems, wherein the aerial system under test is so mounted that its direction can be varied, and including a complementary aerial system arranged to co-operate therewith, the arrangement being such that one of said aerial systems is adapted to transmit signals and the other to receive said signals, and there is provided indicating and/or recording apparatus actuated on the one hand in accordance with the direction of the aerial system under test, and on the other hand in accordance with the setting of control apparatus required to maintain the output from the receiving aerial at a predetermined level.

In carrying out the invention the aerial to be tested may be the transmitting aerial and this is arranged to be rotated about an axis, whilst the receiving aerial is maintained stationary. Normally in such a case the transmitting aerial will be rotated about a vertical axis to determine its directional characteristics in the horizontal plane, whilst in cases in which it is desired to obtain the directional characteristic in a vertical plane provision may be made whereby it can be rotated about a horizontal axis.

Alternatively, of course, the aerial under test may be a receiving aerial, in which case the latter would be rotated and the transmitting aerial maintained stationary.

Whilst the invention is mainly applicable to radio aerials it is also applicable to other types of radiation such as light, heat or sound emitters, for example for obtaining polar characteristics of lamps or loud speakers.

In order that the invention may be more clearly understood, reference will now be made to the drawing left with the Provisional Specification and to the accompanying drawing, which respectively show in block form two examples of radio apparatus embodying the invention, designated Figs. 1 and 2 respectively.

In the arrangement shown in Fig. 1 the transmitting aerial is the aerial under test and this aerial together with transmitting apparatus and recording apparatus are mounted in a cabin which is rotatable about a vertical axis.

The transmitter portion of the equipment comprises an oscillator which is amplitude modulated at a convenient frequency, for example a 3 cm. oscillator modulated with a 100 Kc. square wave. The energy is fed to a normal manually operated attenuator for setting the general level, which attenuator is indicated in the diagram as a setting attenuator, whence the energy passes to the aerial under test through a calibrating

attenuator operated by servo mechanism.

The receiver equipment is placed at some suitable distance from the transmitter and the energy received by the receiver aerial is fed to a rectifier from which is obtained the 100 Kc. square-wave of the modulation. This square-wave undergoes amplification in a tuned amplifier and because of the narrow bandwidth the resultant amplified signal is a sine wave of the fundamental frequency of 75 the square-wave modulation. This sine wave voltage is fed by means of cable back from the receiving station to the transmitter and recording station where, after further amplification and if necessary passage through 80 selective filters to reduce noise level, it passes through a rectifier and thus produces a D.C. voltage. The D.C. voltage is fed into a balancer unit where it is balanced against a stabilised D.C. reference voltage. The output from the balancer is fed to a servo motor and it will be appreciated that the output from the balancer will depend upon the value of the D.C. voltage from the receiver relative to the reference voltage and will 85 operate the servo in one direction or the other according to whether the received signal is greater or less than the reference voltage. The servo motor is operatively connected with the calibrating attenuator in the transmission chain and varies the setting of this so as to increase or reduce the energy fed to the transmitter aerial under test in such a manner as to maintain the received signals constant.

It will thus be appreciated that the apparatus sets itself in such a way that the received signal is at a constant level and is independent of the characteristics of the rectifiers and amplifiers employed, provided 105 that these remain constant during a plot. The accuracy of the apparatus is thus unaffected by ageing of components, such as thermionic valves. At the same time the servo unit operates a recorder unit simultaneously with its operation of the calibrating attenuator so that a record and/or indication is obtained of the setting of the calibrating attenuator necessary to maintain the received signals at a constant level and this will, of course, be a measure of the energy propagated from the aerial under test in the direction of the receiver. Whilst the transmitter or aerial is being rotated the recorder is, at the same time, moved in 110 accordance with the direction of the transmitter aerial.

In the arrangement embodying the invention the servo unit may comprise a D.C. motor whose armature is supplied with 125 constant current and having a split field winding. The balancer unit may for example comprise a pair of valves having a common cathode coupling and the grid voltage of one of these valves is controlled by the rectified 130

- output from the receiver, the grid voltage of the other valve is maintained constant. These valves will respectively control the currents through windings of the servo motor field system which windings would act in opposition, the valves preferably operating through additional amplifying valves. The servo motor may conveniently operate a cam or the like operating the attenuator. The use 5 of a cam enables the attenuation scale to be given any desired characteristic, for example linear or logarithmic. Furthermore, by choice of suitable gearing, any desired angular scale may be achieved. Conveniently means are provided for changing the ratio of the gearing so as to change the angular scale.
- In some cases it may be convenient to provide the servo motor with velocity feedback to maintain stability; this might be obtained by a small tachometer generator giving a voltage feedback proportional to 10 velocity.
- According to one construction the recorder 20 comprises a drum which carries graph paper around its periphery and is rotated through gearing controlled from the movement of the cabin housing the transmitter and recorder apparatus. Thus the angular position 25 of the drum about its axis is proportional to the direction of the aerial under test.
- With such an arrangement recording may be performed by a pen which traverses the periphery of the drum axially and is positioned by the servo motor, for instance by means of a lead screw. With such an arrangement, as the transmitter aerial is rotated, a graph on cartesian co-ordinates 30 may be obtained showing the variation in field strength at constant distance from the aerial under test as a function of bearing.
- The recording apparatus may alternatively 35 be photographic, obtained for instance by deflecting an electron beam falling on a fluorescent screen having a backing of photographic material. In some cases a visual indication may be obtained by such apparatus where the fluorescent screen has a long afterglow; such visual indication 40 may be in lieu of or supplementary to recording apparatus.
- Alternatively it will be appreciated that the transmitter and recorder cabin may be 45 stationary and only the aerial under test rotated, the recorder in such a case being controlled mechanically or otherwise in accordance with the position of the aerial under test.
- It is contemplated that in employing such 50 apparatus the aerial under test will be moved relatively rapidly through the range of positions over which the graph is to be obtained by the recording apparatus.
- In a model for testing 3 cm. aerials, the 55 oscillator is a small reflex klystron pulsed with equal mark-space ratio at 100 kc/s. repetition and the attenuator takes the form of a piece of carbon-coated "Bakelite" (Registered Trade Mark) paper sheet which is pushed into the waveguide system by means of a cam operated by the servo motor. In this case the receiving aerial is a parabolic dish and the signal rectifier is a silicon crystal.
- One of the limits to sensitivity is noise level and in order to minimise this it is desirable that the overall bandwidth of the amplifier system should be as small as possible. In order to obtain a narrow bandwidth quartz crystal filters may be introduced at suitable 60 points in the circuit.
- An alternative way of obtaining narrow bandwidth is to replace the rectifier immediately prior to the balancer unit by a mixer arrangement. In this, the normal type of multigrid mixer valve may be used, the signal grid being connected to the incoming modulation signal (sine wave) from the receiver whilst the injection grid is connected, through suitable phasing networks, to the sine wave generator controlling the pulsing of the oscillator. Thus in the mixer two signals of identical frequency (f) are mixed, producing a D.C. voltage, and a voltage of frequency $2f$. (These take the place of voltages of frequencies $f_1 - f_2$ and $f_1 + f_2$ of the normal type of mixer). Any noise from amplifiers, etc., will produce voltages of frequencies from zero up to some 65 frequency F determined by the bandwidth of the amplifier. By passing the output from the mixer through a low pass filter the noise can be largely eliminated and the D.C. passed to the balancer unit. It will be appreciated that in the original scheme when a normal rectifier is used, both noise and signal produce a D.C. voltage and no further filtering is possible.
- Further it will be appreciated that a 70 balanced type of mixer may be employed if desired.
- Instead of using a steady D.C. reference voltage in the balancer unit a small fraction of the oscillator power may be rectified to 75 produce a voltage proportional to the oscillator power and this voltage may be used as the reference voltage. This eliminates error due to variation of oscillator power during the plotting of a curve.
- According to a further feature means are provided for varying the speed of rotation of the aerial under test in accordance with the rate of change of the attenuator position; this enables curves to be plotted at maximum 80 average speed since the aerial may be rotated relatively slowly over those portions where the rate of change of the attenuator position is great and relatively rapidly over those portions where the rate of change of the 85

- attenuator position is small.
- The maximum speed of aerial rotation is of course under any conditions limited to such a speed that the servo mechanism operating the attenuator may accurately follow the variations. A particular manner of achieving this is to control the speed of rotation of the hut by a servo mechanism which in turn is controlled by the magnitude of the voltage generated by the tachometer generator associated with the attenuator servo mechanism. This voltage is of course proportional to the rate of change of the attenuator setting.
- Referring to the accompanying drawing, Fig. 2 shows, as an alternative, the arrangement in which the receiving aerial is the aerial under test. Here the transmitter and transmitting aerial are fixed and the receiver and receiving aerial are arranged to be rotated. The receiver and associated recording gear may be conveniently situated in a rotatable cabin the recording gear being operated in a similar manner to that described above.
- In this case the signal picked up by the receiving aerial is passed via a calibrating attenuator and setting attenuator to a rectifier at the output of which the square wave modulation is obtained. This is then passed via a narrow band tuned amplifier, which separates out the fundamental sine wave to a further rectifier unit which produces from it a proportional D.C. voltage. This D.C. voltage is then fed to a balancer and servo-mechanism arrangement operating as before, the servo-mechanism operating the calibrating attenuator to maintain the signal and also controlling the recording mechanism.
- It will be appreciated that the additional stages of amplification may be inserted in the receiver channel if required.
- One advantage of the arrangement over the previous one is that no cable link is required between receiver and transmitter.
- It is obviously not convenient in this second arrangement to tap off a portion of the oscillator power at the transmitter to give a reference level for the balancer, as was described with reference to the first arrangement. However, if a reference level other than a steady D.C. potential is required this may be obtained by having an additional aerial and receiver located at the receiving station to give a measure of transmitter power. If the additional aerial is arranged to be rotated with the test aerial it must, of course, have a highly uniform radiation pattern, but if arranged to be stationary it can have directive properties. In either case care must be taken to ensure that the additional receiving aerial does not upset the radiation pattern of the aerial under test.
- Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—
1. Apparatus for determining the directional characteristics of wave propagating and/or receiving apparatus including means for causing said apparatus to transmit waves to, or receive waves from, co-operating apparatus, means for moving said apparatus under test angularly with respect to said co-operating apparatus, control apparatus acting on the propagating or receiving apparatus in such a manner as to give a substantially constant amplitude output from the receiving apparatus and means whereby the setting of the control apparatus provides a measure of the relative efficiency of the apparatus under test at different angular positions. 70
 2. Apparatus for determining the directional characteristics of radio aerial systems, in which the aerial system under test is so mounted that its direction can be varied, and in which a complementary aerial system is arranged to co-operate therewith, the arrangement being such that one of said aerial systems is adapted to transmit signals and the other to receive said signals, and there is provided indicating and/or recording apparatus actuated on the one hand in accordance with the direction of the aerial system under test, and on the other hand in accordance with the setting of control apparatus required to maintain the output from the receiving aerial at a predetermined 75 level. 80
 3. Apparatus as claimed in Claim 2, in which the rectified output from receiving apparatus associated with the receiver aerial is fed to a balancer stage, wherein it is balanced against a D.C. reference voltage to produce an output voltage, said output voltage being fed to servo-mechanism so as to operate control apparatus and also indicating and/or recording apparatus in accordance with the magnitude and sign of said output voltage. 90
 4. Apparatus as claimed in either of the preceding Claims 2 or 3, comprising a rotatable cabin on which is mounted said aerial system under test, said cabin housing associated transmitting or receiving system together with control equipment, also indicating and/or recording apparatus. 95
 5. Apparatus as claimed in any of the preceding Claims 2—4, in which said recording apparatus comprises a drum which is rotated in accordance with the rotation of said aerial system. 100
 6. Apparatus as claimed in any of Claims 2 to 5, in which means are provided for varying the speed of rotation of the aerial under test, in accordance with the rate of setting of the control apparatus. 110
 7. Apparatus as herein described with 120

reference to the drawing left with the Dated the 19th day of October, 1948.
Provisional Specification.

8. Apparatus as herein described with J. W. RIDDING,
reference to the accompanying drawing. Chartered Patent Agent,
162, Shaftesbury Avenue, London, W.C.2,
Agent for the Applicants.

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copies, price 2s. Od. each (inland) 2s. 1d. (abroad) may be obtained.

TRANSMITTER
AND RECORDER.

[This Drawing is a reproduction of the Original on a reduced scale.]

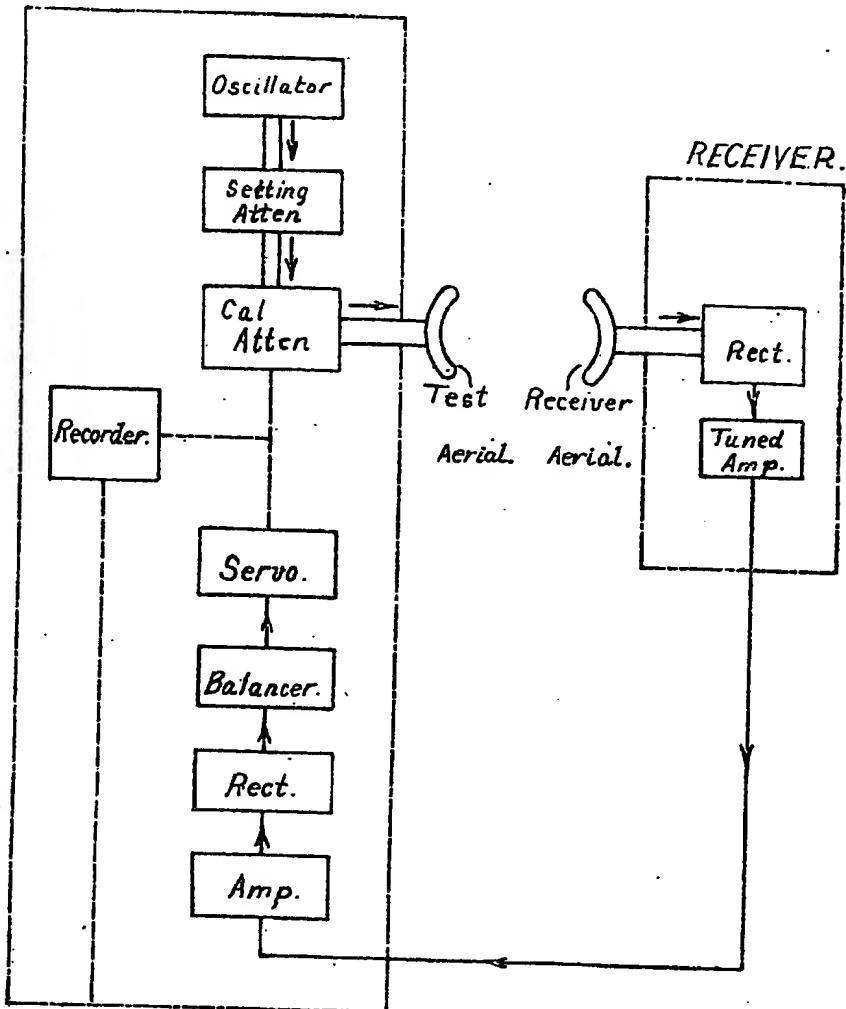


FIG. 1.

[This Drawing is a reproduction of the Original on a reduced scale.]

Receiver
And
Recorder.

Transmitter.

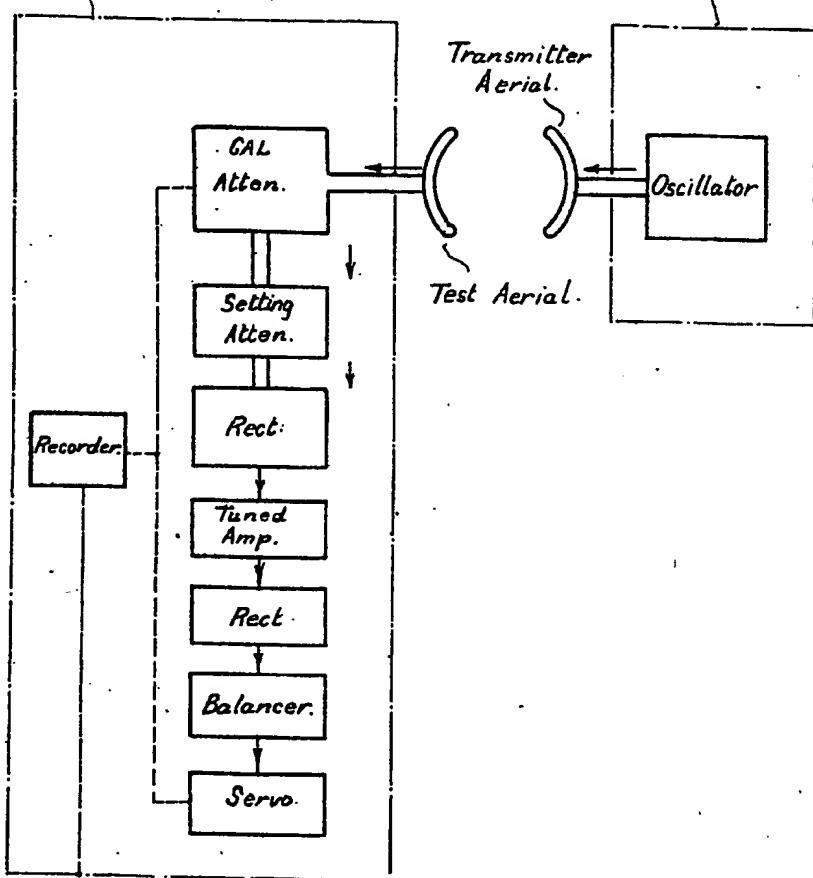


FIG. 2.